

# Development of a Bioenergetics Model for Brown Shrimp (*Farfantepenaeus aztecus*) and the Potential Effects of Freshwater Diversions on Shrimp Production



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## INTRODUCTION

Wetlands in coastal Louisiana have suffered extensive land loss over the past century. One method that is being used to restore coastal wetlands in Louisiana is diverting freshwater from the Mississippi River into nearby estuaries. While it is known that freshwater diversions can help to restore coastal wetlands, their effects on coastal fisheries is less clear. In the case of brown shrimp (*Farfantepenaeus aztecus*), freshwater diversions may affect the production of juvenile shrimp through the direct effects of changing temperatures on shrimp growth rates and the indirect effects of altered prey availability due to changes in salinity.

## MODEL DEVELOPMENT

### Methods

To investigate the effects of freshwater diversions on the production of juvenile brown shrimp, we developed a bioenergetics model for shrimp using a Bayesian framework. We used a modified version of the Wisconsin bioenergetics model which uses a mass-balance approach to predict growth. The model is:

$$\text{Growth} = \text{Consumption} - \text{Metabolism} - \text{Unassimilated food}$$

The model predicts shrimp growth rates as a function of shrimp weight, water temperature, and salinity. Salinity was a multiplier to the consumption term to account for salinity effects on prey availability (Rozas, unpublished data).

We simulated shrimp growth rates for all combinations of temperature (5, 10, 15, 20, 25, 30, 35, 37°C) and salinity (2, 5, 10, 15, 20, 25, 30). Predicted growth rates were corroborated by comparing observed growth rates from two data sets to the predicted growth rates. Parameter values were correlated so for each temperature and salinity combination we simulated 1000 individual shrimp. This resulted in a distribution of predicted growth rates for each combination of temperature and salinity.

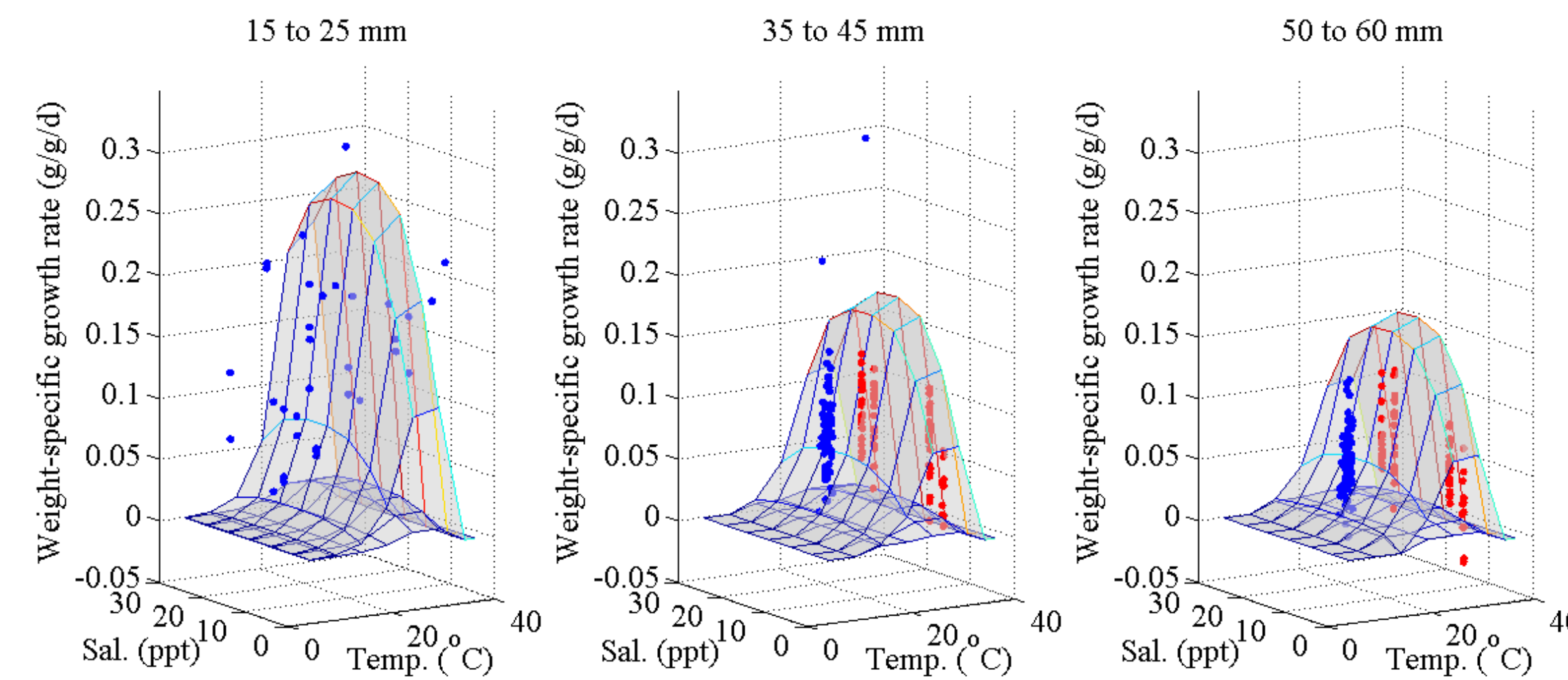
### Results

Predicted growth rates compared favorably with field observations with 84% of the observations used to fit the model, and 99% of observations from an independent data set, falling within the middle 95 percentile envelop of predicted growth rates (Figure 1). The model was weakest at predicting growth rates for small shrimp (15-25 mm long shrimp), often underestimate growth. The model was better at predicting growth rates for the 35-45 mm and 50-60 mm long shrimp, slightly over estimating the growth rates of the slowest growing shrimp.

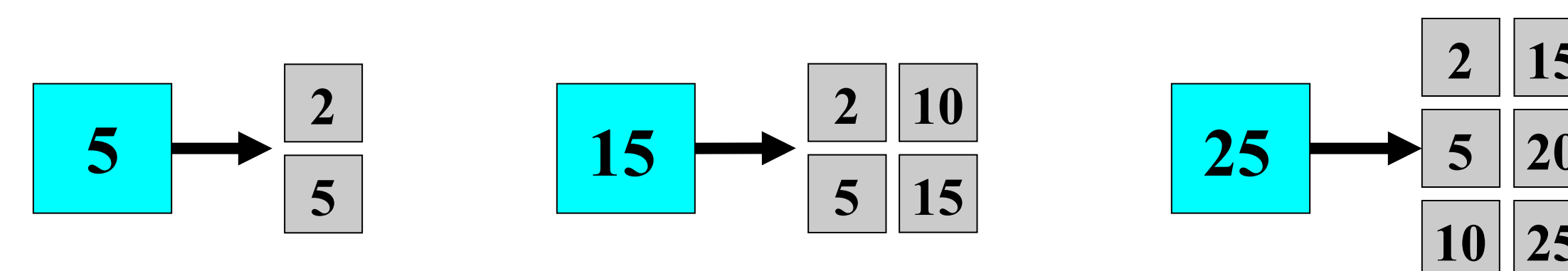
## MODEL APPLICATION

### Methods

To determine the effect of diversions on shrimp production, we developed a series of simulations that varied the timing (month), duration (days), initial salinity, salinity during the diversion, change in water temperature during the diversion (°C) and prey response time to changes in salinity (d). We simulated the effects of the diversion starting in February, March, April, and May. Diversions started on the first day of each month and ran continuously for 14, 30, or 60 days. Scenarios with 14-d diversions had two separate diversions, starting on the first day of each month for two consecutive months (e.g. Feb. 1-14 and Mar. 1-14). We only started 30-d diversions in May, as 14-d and 60-d diversions would result in diversions during June. We simulated sites at three points along a salinity gradient (5, 15, 25).



**Figure 1** Predicted growth rates of juvenile brown shrimp for three size intervals (15-25, 35-45 and 50-60 mm). The lower and upper surfaces show the 2.5th and 97.5th percentiles of predicted growth rates. Blue dots show observed growth rates used to fit the model while red dots show observed growth rates for an independent data set.



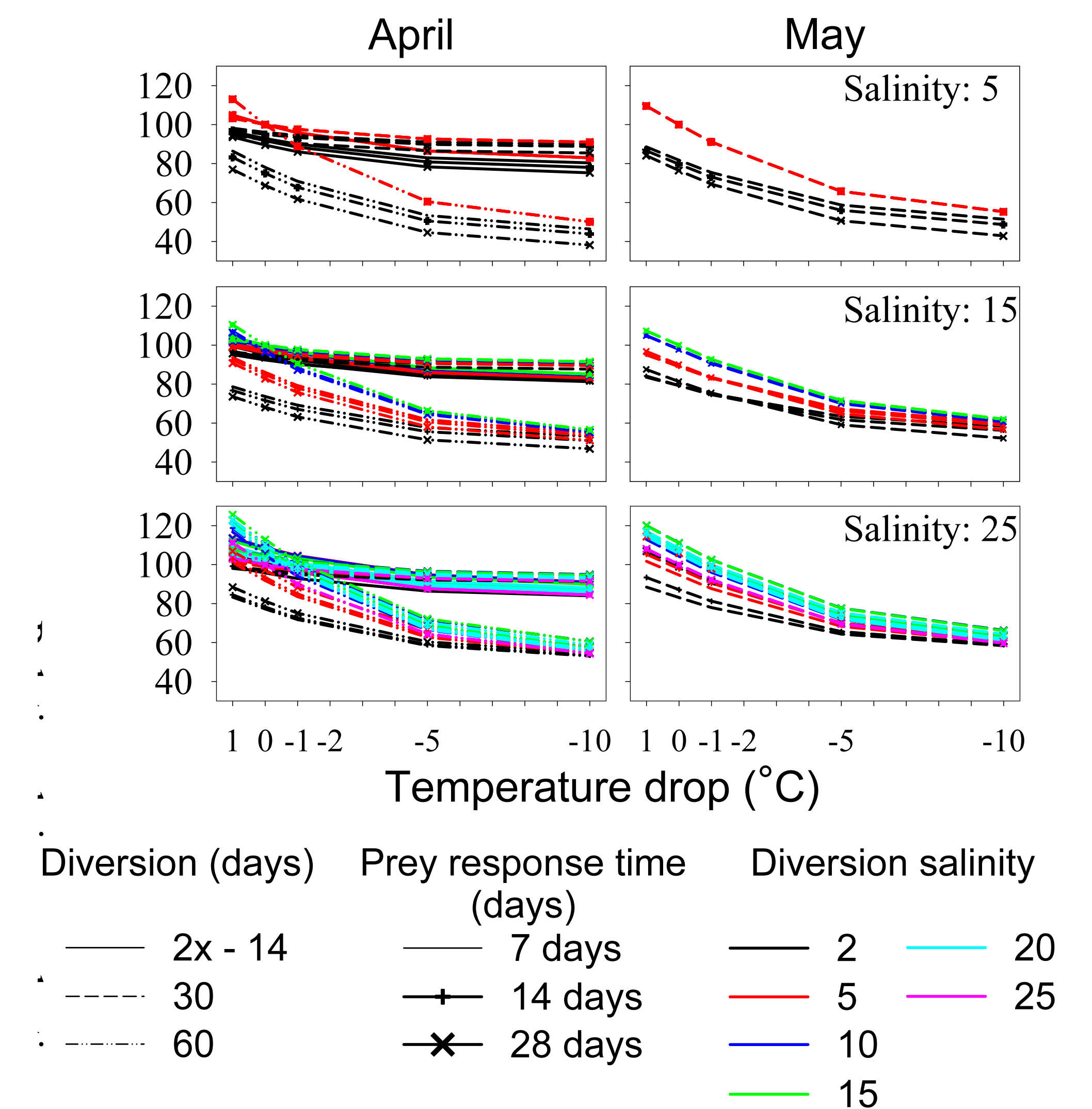
**Figure 2.** Salinity during freshwater diversions. Cyan boxes show the initial salinity, grey boxes show the salinities that were simulated during freshwater diversion for each of the initial salinities.

For each of the sites, we simulated salinity dropping to a range of values (Figure 2) during the diversion. We also simulated five potential temperature changes during the diversion (+1, 0, -1, -2, -5, -10°C) and three prey response times (time it took for shrimp prey availability to respond to salinity changes).

For each scenario, we simulated the growth and mortality of weekly cohorts of shrimp. Simulations ran from January 1st to August 1st. Water temperatures were derived from multi-year temperature records for Barataria Bay. Shrimp mortality was size-dependent, with smaller shrimp dying at a higher rate than larger shrimp. Each weekly cohort of shrimp had 1000 model individuals, each with an initial length of 15 mm. For each simulation, we determined the total biomass of 75-mm long juvenile shrimp produced by the simulation because that is the approximate length at which juvenile shrimp leave coastal wetlands for open water. We standardized total biomass for each scenario using the total biomass of shrimp produced for the no diversion scenario (i.e. temperature change = 0, initial salinity = diversion salinity) associated with the initial salinity of the scenario.

### Results

Diversions starting in February and March had little effect on shrimp production relative to the no diversion scenarios. Sixty-day diversions starting in April and 30-day diversions starting in May had the largest effects on shrimp production (Figure 3). Shrimp production generally decreased when diversions caused a drop in water temperature (and increased when water temperature increased). Bigger temperature drops caused bigger reductions in shrimp production, however the incremental effect of temperature decreased as the magnitude of change increased. The effect of a decrease in salinity during a diversion depended on the initial salinity. For scenarios with an initial salinity of 5 or 15, decreases in salinity during the diversion resulted in a reduction in shrimp production. For the 25 salinity scenario, large reductions in



**Figure 3.** Relative shrimp production for April and May for sites with initial salinities of 5, 15 and 25.

salinity (dropping to 2 or 5) reduced shrimp production relative to the no salinitydrop scenarios (pink lines). However, smaller reductions in salinity (salinities of 10, 15, or 25, blue, green, and cyan lines respectively) resulted in an increase in shrimp production relative to the no salinity drop scenarios. Increases in shrimp production were caused by an increase in prey availability as prey biomass was higher at salinities of 15-20 than at 25.

## CONCLUSIONS

- 1) Diversions during February and March have a smaller effect on shrimp production than diversions in April and May.
- 2) Shorter diversions affect shrimp production less than longer diversions.
- 3) Bigger changes in temperature and salinity have bigger effects on shrimp production.
- 4) Whether salinity effects on shrimp production are positive or negative depends on the initial salinity of the site.
- 5) It is possible to have diversions during April and May that have only small ( $\pm 10\%$ ) effects on shrimp production (Figure 3, April), but it is strongly dependent on site specific conditions.

## QUESTIONS? CONTACT INFORMATION:

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